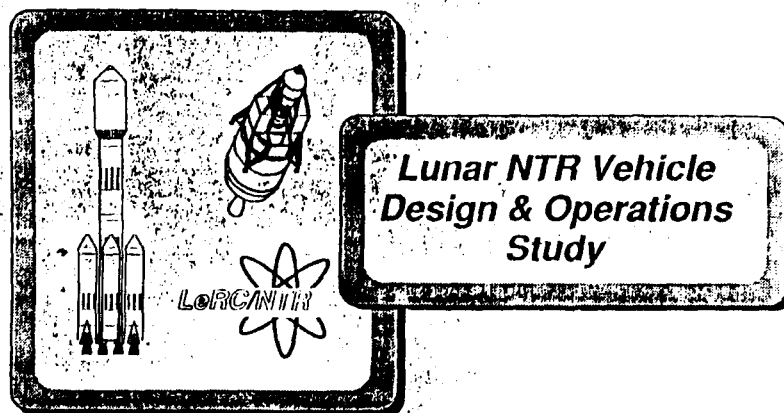


N93-26922



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J11921007 00A

LTS/NTR Design & Operations Study



Objectives

Perform an Evaluation of the Potential Applications of a Specific Nuclear Thermal Rocket (NTR) Design to Past and Current (First Lunar Outpost) Mission Profile(s) for Piloted and Cargo Lunar Missions, and to Assess the Applicability of Utilizing Lunar Vehicle Design Concepts for Mars Missions

Products

- Assess NTR Propulsion For Lunar Vehicle Concepts Based on Existing Mission Profiles
- Define and Size the Stage/Transfer Vehicles for Lunar NTR Applications
- Perform an Operational and Programmatic Assessment
- Perform a Chemical/NTR Lunar Concept Comparison

Lunar Orbit & Direct Design Concepts
Key Subsystem & Operations Sensitivities
Mars Growth/Evolution Approach

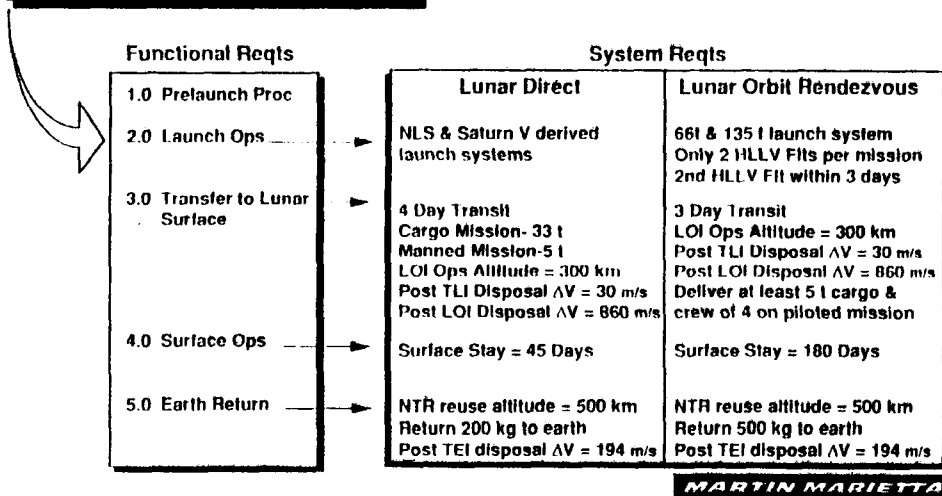
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Reqs Provide Basis for NTR Vehicles



Mission Statement

- Support Exploration & Habitation of Lunar Surface with consideration for evolvability to Mars
- Lunar IOC 2000-2005
- Mars IOC: 2005 Cargo 2007 Piloted

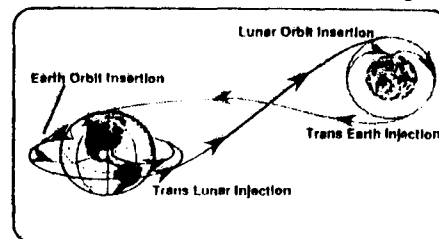
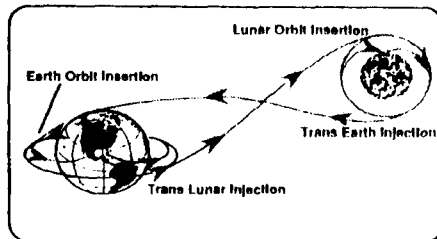


1 R920812 System Req

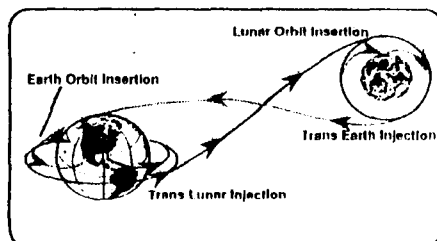
Lunar Mission Options



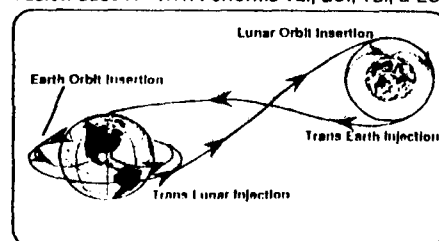
Mission Case I - NTR Performs TLI



Mission Case II - NTR Performs TLI & LOI



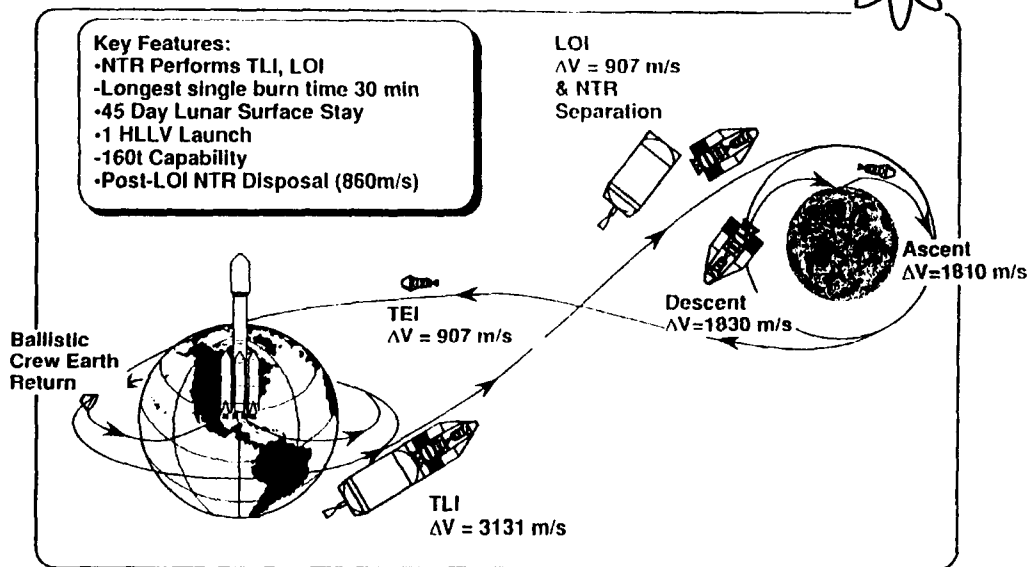
Mission Case III - NTR Performs TLI, LOI, & TEI



Mission Case IV - NTR Performs TLI, LOI, TEI, & EOC

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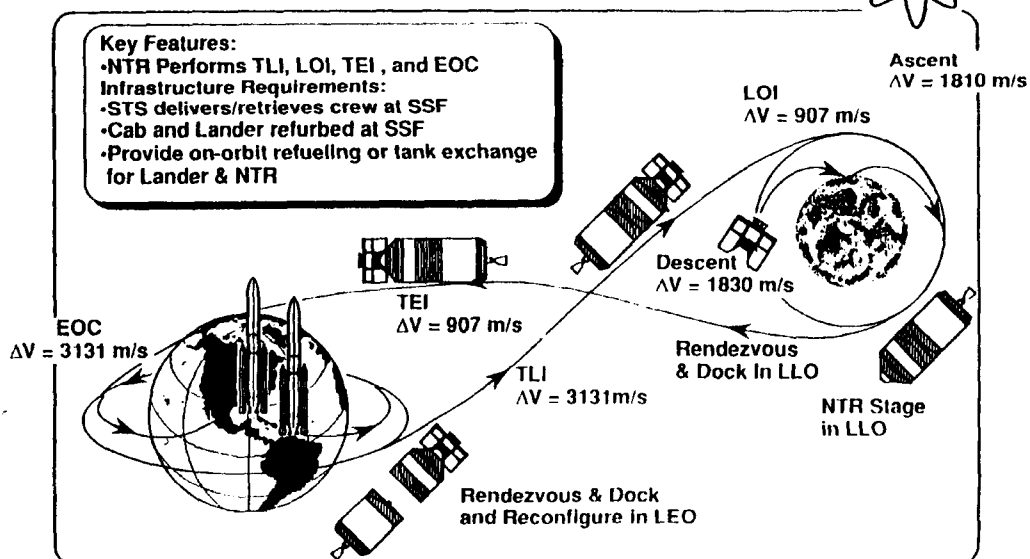
LD Space Operations Overview



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LD921009-LD Ops

LOR Space Based Operations Overview



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LD921009-LOR Reuse Ops

System Design Considerations



- **Expendable vs. Reusable**
 - Operations Complexity Too High For Reusability
 - Performance Maximization Achieved With Expendable Mission
 - Safety Concerns Lessened With Expendable Mission
- **Shielding Considerations**
 - NERVA Disk Shield
 - Modified Disk Shield Optimizes Design and Use of Propellant
 - Propellant and Tankage
 - Lander Propellant and Structure
- **Launch Vehicle Considerations**
 - Lunar Direct Mission
 - Smallest Launch Vehicle Necessary to Complete FLO Mission
 - Lunar Orbit Rendezvous
 - Complete Reasonable Lunar Architecture
 - Using Medium Sized Launch Vehicle
- **Thermal Protection Considerations**
 - Active Refrigeration Too Heavy For Benefit & Abort Mission If Failed MLI & SOFI
- **Lander Considerations**
 - Lunar Direct Mission
 - 2 Stage Cryo/Storable Removes Long Term Hydrogen Storage on Orbit
 - Lunar Orbit Rendezvous
 - 1 1/2 Stage Cryo/Cryo Out-performs 2 Stage
 - Lander Consistently in Past STV Studies
- **Material and Construction Considerations**
 - Aluminum Lithium Technology On Schedule For Flight Use By 2005
 - Isogrid Construction Promising For Structural Considerations
- **Engine Configuration**
 - Single vs Cluster
 - 25k vs 50k vs 75k

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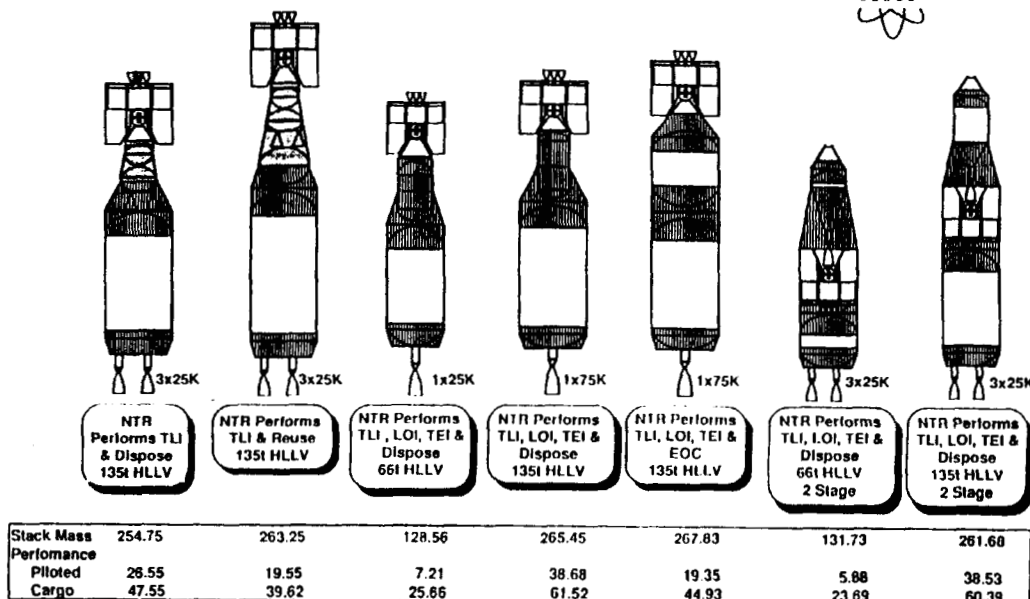
Lunar Orbit Rendezvous Configurations

The chart below shows the top seven candidates of the Lunar Orbit Rendezvous configurations. We started with eighteen possible configurations in this category, and through performance runs, design constraints and operational issues, that eighteen was narrowed to the following seven. The missions that utilized a cryogenic liquid oxygen and liquid hydrogen TEI stage were extremely close in performance to those missions using NTR to perform the TEI burn. Therefore, it was beneficial to show the elimination of an entire technology, use of a LOX/LH₂ stage, and to show that a lunar mission can be supported solely by NTR technology. Another criteria that eliminated candidates was performance at least 5.00 tonnes to the lunar surface on a piloted mission. Also eliminated in the earlier phases of the study were two HLLV candidates. We started with four HLLV candidates: 66t, 105t, 132t, and 135t launch capacities. We narrowed that field to two candidates based on past STV analysis showing the 132t and 135t vehicles virtually even on performance. Of the three that were left, 66t, 105t, 135t, we eliminated the 105t because of study complexity and to demonstrate that NTR can be utilized on the two extreme launch vehicles and, therefore, everything in between.

Three of the configurations shown below started with a cluster of three 25Klb_r NTR engines, but with further analysis their performance was greatly enhanced by going to a single engine configuration. Also, two of the configurations are two stage NTR configurations. The first NTR stage performs the TLI burn and is then staged off to perform a lunar assist disposal burn into heliocentric space. The second NTR stage then performs the rest of the mission and is also disposed of after the TEI burn.

LP00803 LP OR Configs

Lunar Orbit Rendezvous Configurations

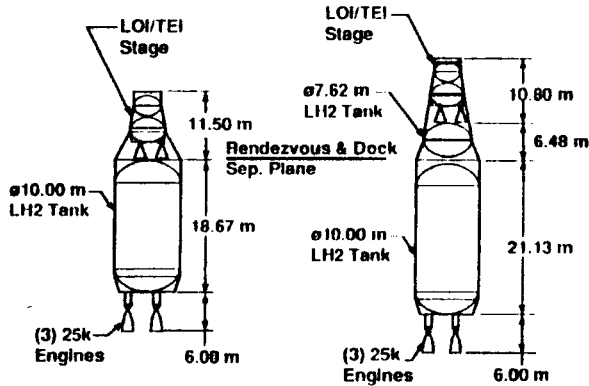


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Lunar Orbit Rendezvous Configurations

NTR Performs TLI and Disposed
NTR Performs TLI and Reused



LOI/TEI Stage Component	TLI & Dispose t	TLI & Reuse t
Structure	2.46	2.39
Tankage	0.99	0.93
Subsystems	2.83	2.83
Engine Structure	0.51	0.51
Engines	0.80	0.80
Contingency (15%)	1.14	1.12
Total Dry	8.73	8.58
Propellant	41.18	35.71
Total Wet	49.91	44.29

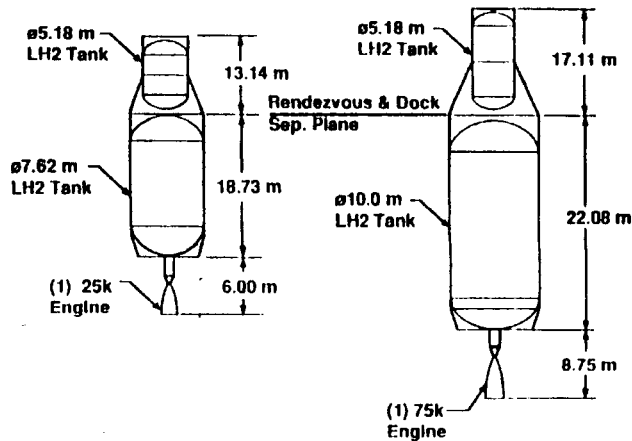
NTR Stage Component	TLI & Dispose t	TLI & Reuse t
Structure	8.87	1.83
Tankage	5.10	7.20
Subsystems	2.11	2.64
Engine Structure	0.75	0.86
Engines	11.18	11.18
Shield	0.08	0.08
Contingency (15%)	3.00	3.56
Total Dry	23.01	27.27
Propellant	91.88	116.13
Total Wet	114.89	143.40

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Lunar Orbit Rendezvous Configurations

NTR Performs TLI, LOI, TEI and Disposed - 66t HLLV & 135t HLLV

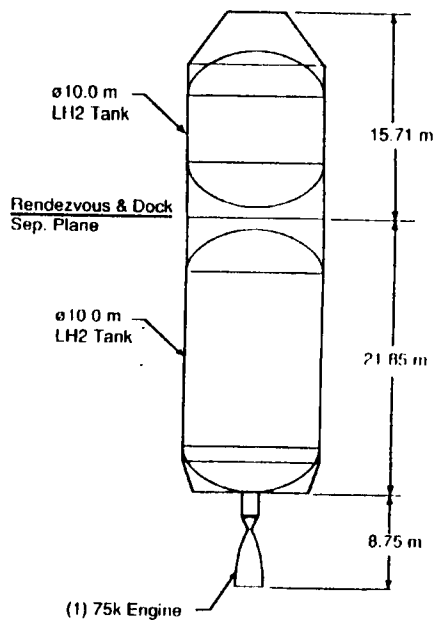
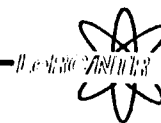


NTR Stage Component	66t	135t
Structure	1.37	1.95
Tankage	3.71	6.80
Subsystems	1.98	2.87
Engine Structure	0.41	0.96
Engine	3.73	6.83
Shield	1.50	4.50
Contingency (15%)	1.91	3.59
Total Dry	14.61	27.50
Propellant	63.73	123.09
Total Wet	78.34	150.59

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Lunar Orbit Rendezvous Configurations

NTR Performs TLI, LOI, TEI and EOC - 135t HLLV



NTR Stage

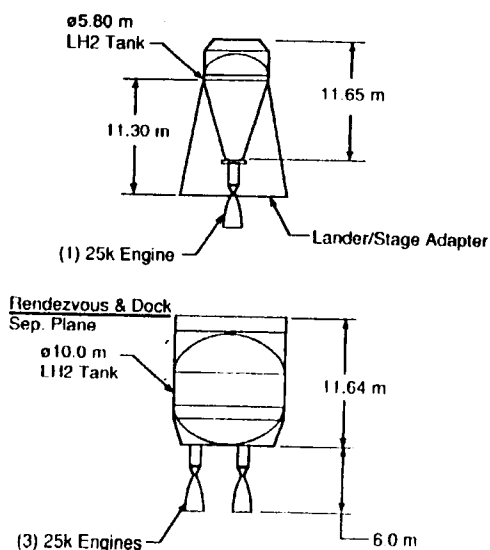
Component	t
Structure	2.91
Tankage	9.70
Subsystems	3.45
Engine Structure	0.96
Engine	6.83
Shield	4.50
Contingency (15%)	4.25
Total Dry	32.60
Propellant	160.08
Total Wet	192.68

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Lunar Orbit Rendezvous Configurations

2 Stage NTR Performs TLI, LOI, TEI and Dispose - 66t HLLV



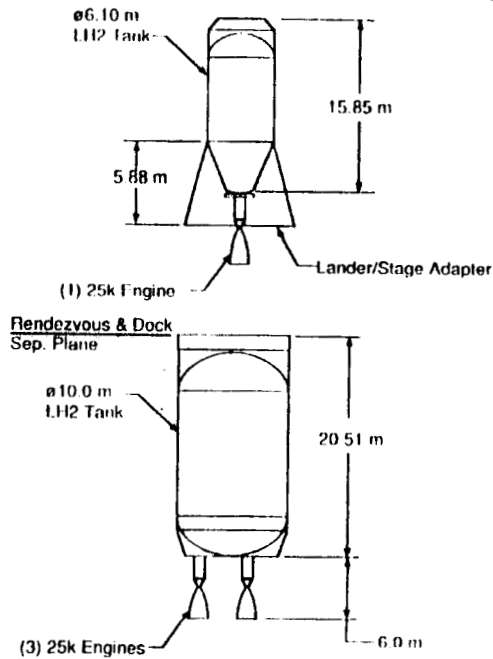
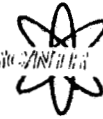
NTR Stage 1 & 2

Component	t
Structure	2.59
Tankage	4.50
Subsystems	1.69
Engine Structure	0.76
Engine	14.91
Shield	1.50
Contingency (15%)	3.89
Total Dry	29.84
Propellant	54.42
Total Wet	84.26

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Lunar Orbit Rendezvous Configurations

2 Stage NTR Performs TLI, LOI, TEI and Dispose - 1351 HLLV



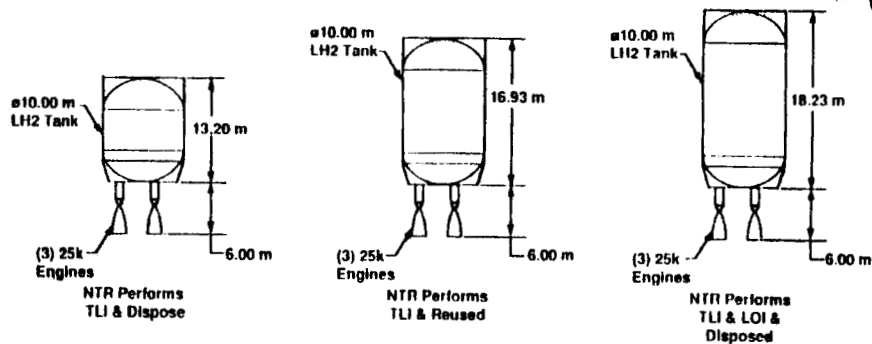
NTR Stage 1 & 2

Component	t
Structure	1.79
Tankage	8.60
Subsystems	2.73
Engine Structure	0.81
Engine	14.91
Shield	1.50
Contingency (15%)	4.25
Total Dry	32.59
Propellant	114.55
Total Wet	147.14

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Preliminary LD NTR/TLI Configurations



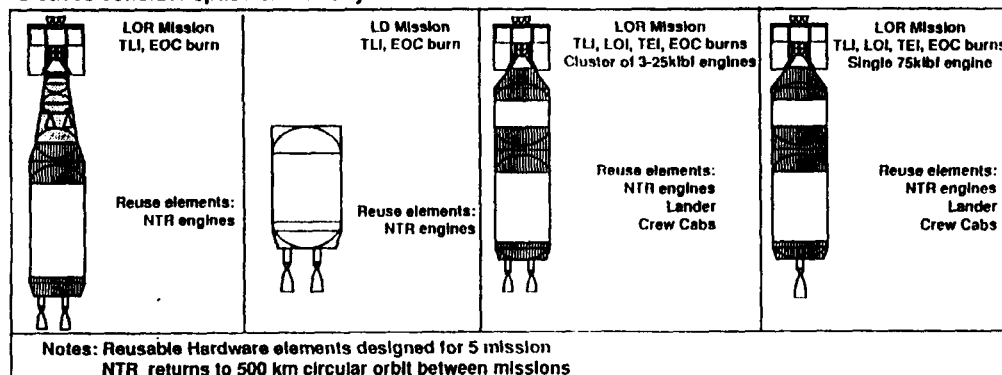
NTR Stage	TLI & Dispose	TLI & Reuse	TLI, LOI & Dispose
Component	t	t	t
Lander/TLI Adapter	1.49	1.49	1.49
Tankage	4.40	5.20	5.50
Subsystems	.81	.93	.97
Engine Structure	2.01	2.29	2.38
Engine	11.18	11.18	11.18
Shield	0.00	0.00	0.00
Contingency (20%)	3.98	4.22	4.30
Total Dry	23.87	25.31	25.82
Propellant	59.60	80.64	87.96
Total Wet	83.47	105.95	113.78

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NTR Reuse Examined in Study



- Developed vehicle mass properties, payload capabilities, space operations
- 2 cases consider reuse for NTR only
- 2 cases consider space based fully reusable vehicles



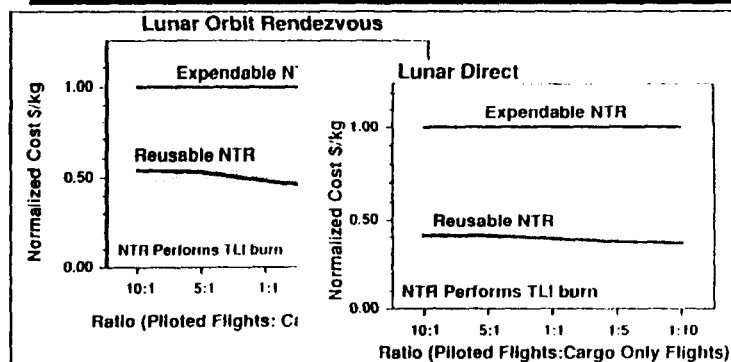
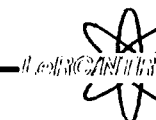
- Identified infrastructure needs (assumed existing)*
- STS for crew delivery/retrieval
- SSF for refurb
- Capability for on-orbit refueling or tank exchange

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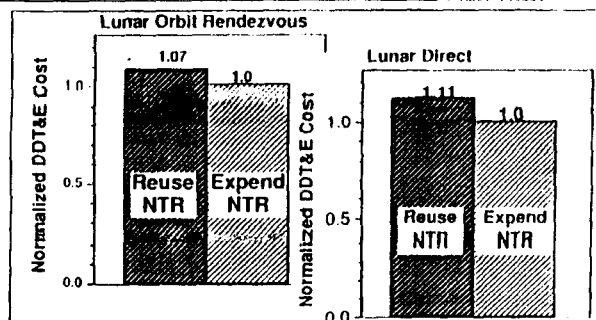
*Infrastructure costs (elements & associated operations) were not included in cost analysis

LA920819 REUSE GRD RULES2

Reuse Cost Analysis



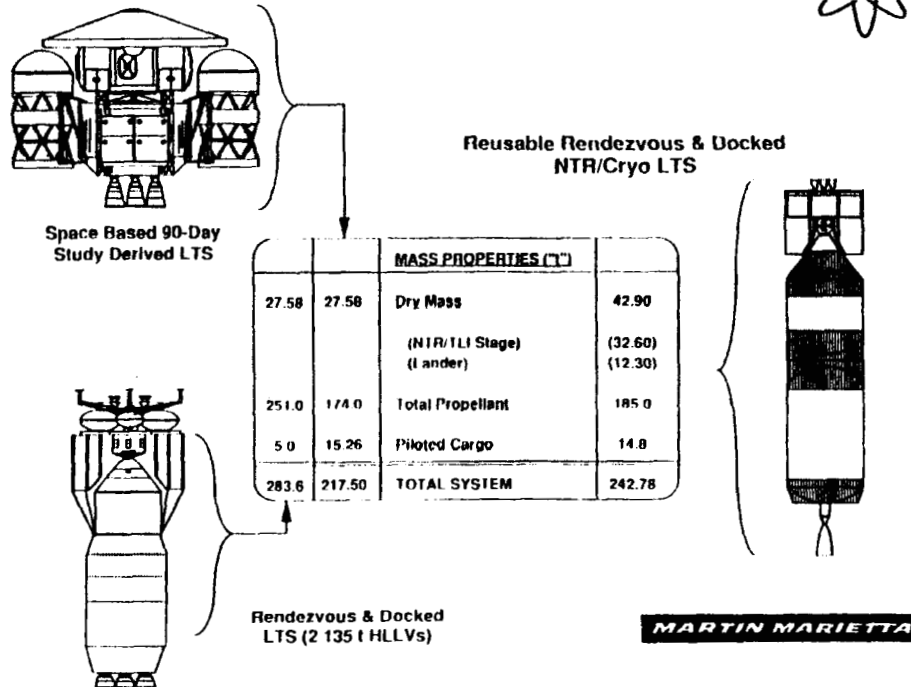
Reuse Reduces
Vehicle Recurring
Cost approximately
50%



Reuse Increases
Vehicle DDT&E
approximately 10%

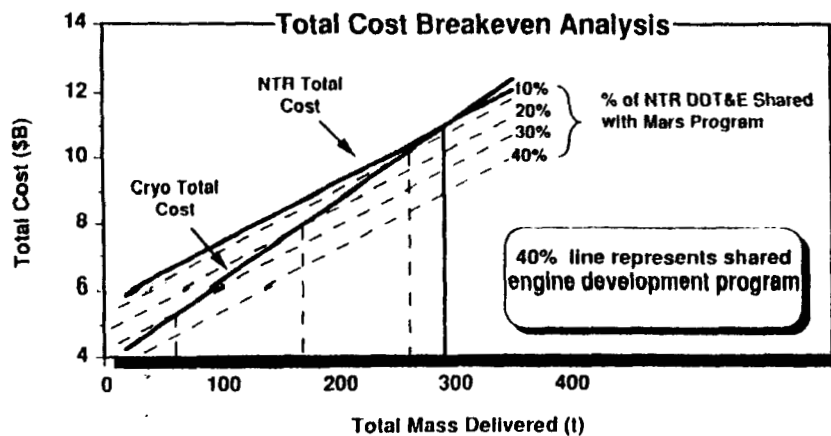
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NTR/Cryo Reusable System Comparison



NP21016-10A

Mars Evolution Key to Affordability



Sharing Development Cost of Common Elements with Mars Program Lowers Total Cost of Lunar Missions

Example: Splitting the engine development cost between the lunar and Mars programs shifts breakeven point from 300 t to less than 50 t

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Conclusions



• Near term NTR Provides Feasible Alternative to Cryo system for Lunar Missions

-Performance

NTR LD concept offers smaller IMLEO for same payload capability as cryo system

NTR LOR offer greater payload delivery capability for same IMLEO

-Cost

NTR more cost efficient (\$/kg) than cryo system

NTR Development cost greater than cryo systems

-Ops

LOR option requires on-orbit cryo transfer (technology risk)

-Schedule

1st cargo launch capability in 2002

• Near term NTR enable efficient evolution to Mars

-Cost

Shared development cost of common elements enhances affordability

Hardware commonality

-Mission

Lunar NTR adaptable to wide range of mission architectures (Direct, MOR)

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LR921009 Conclusion